Original Article

Body Composition, Limb Symmetry, and Functional Outcomes after ACL Injury: Insights from Sports Injury Patients in a Bangladeshi Orthopedic Department

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ABSTRACT:

Background: *Anterior cruciate ligament (ACL) injury is a frequent and disabling problem among sports injury patients. Body composition and muscle asymmetry are suspected risk factors, but evidence from Bangladeshi clinical populations is limited.*

Objective: *To investigate the association of body composition and limb symmetry with ACL injury among sports injury patients attending the Department of Orthopedic Surgery, Bangladesh Medical University.*

Methods: *This cross-sectional study was conducted over one year (January 2023–December 2023) and included 92 sports injury patients (74 without ACL injury; 18 with prior ACL injury). Anthropometry, bioelectrical impedance (or skinfolds), and thigh circumference/lean mass were measured, and limb symmetry indices (LSI) were calculated. In the ACL-injured subgroup, functional outcomes were assessed using KOOS (Knee injury and Osteoarthritis Outcome Score) and IKDC (International Knee Documentation Committee). Logistic regression adjusted for age, sex, sport type, and weekly training exposure examined associations, while AUC and calibration assessed model performance.*

Results: *Patients with ACL injury had higher body fat % (21.9 vs 18.6), lower thigh symmetry (92.4% vs 96.9%), and greater weekly exposure (9.0 vs 7.4 h). Adjusted models showed body fat % (aOR 1.42, 95% CI 1.06–2.02) and reduced thigh symmetry (aOR 0.69, 95% CI 0.50–0.95) were significant predictors, while BMI was not. The combined model achieved an AUC of 0.77. Within the ACL subgroup, higher body fat % predicted poorer KOOS-QoL (β=−4.5, p=0.01), and better symmetry predicted less pain (β=+3.8, p=0.01). Sensitivity analyses confirmed these findings.*

Conclusions: *Excess adiposity and reduced limb symmetry were independently associated with ACL injury and worse functional outcomes in sports injury patients. Screening beyond BMI, focusing on body composition and muscular balance, may support targeted prevention and rehabilitation in orthopedic practice.*

Key Words:
Anterior cruciate ligament, body fat percentage, limb symmetry index, cross-sectional study, knee function, Bangladesh.

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Introduction

Anterior cruciate ligament (ACL) injury is one of the most common and debilitating knee injuries encountered in sports medicine and orthopedic practice. It often occurs via noncontact mechanisms during deceleration, cutting or pivoting movements, imposing substantial morbidity, cost, and long-term risk of osteoarthritis [1,2]. In Bangladesh and similar settings, sports injury patients presenting to orthopedic departments frequently include ACL cases, yet local evidence on modifiable risk factors remains limited.

Traditional risk models have focused on demographics and neuromuscular control — such as female sex, limb alignment, muscle strength imbalances, and biomechanical loading [3,4]. In recent years, however, body composition, particularly adiposity, is gaining attention as a contributor to musculoskeletal injury risk. Excess fat mass may increase joint loads, impair neuromuscular coordination, and alter movement mechanics [5]. Indeed, several studies have found that individuals with knee injuries or ACL reconstruction tend to present with higher body fat percentages compared to matched controls [6,7]. For example, a cross-sectional study reported that women with ACL reconstruction had significantly greater % fat mass than healthy peers [6]. Another investigation of musculoskeletal tissue asymmetry after ACL reconstruction revealed differential fat percentage and lean mass distribution between limbs [7].

Parallel to composition, limb symmetry — often expressed as a Limb Symmetry Index (LSI) — reflects balance between sides in muscle mass, strength, or function. Persistent asymmetries after injury or surgery are associated with poorer outcomes and increased risk of re-injury [4,8]. In ACL cohorts, lower LSI in strength or lean mass has been linked to mechanical deficits and reduced return-to-sport safety [8]. Moreover, as obesity or higher adiposity may exacerbate asymmetrical loading, the combined effect of body fat and symmetry deficits merits further investigation.

Despite these emerging insights, few studies have been conducted among sports injury patients in low-resource clinical settings, and little is known about how adiposity and limb symmetry jointly relate to ACL injury status. To address this gap, we conducted a cross-sectional study in the Department of Orthopedic, Bangladesh Medical University over one year, enrolling sports injury patients with and without prior ACL injury. We hypothesized that higher body fat percentage and reduced limb symmetry would be independently associated with ACL injury status, and among injured patients, linked with worse functional outcomes. The findings could inform screening and targeted preventive strategies in orthopedic practice in Bangladesh and similar contexts.

Methodology

This cross-sectional study was conducted in the Department of Orthopedic Surgery, Bangladesh Medical University, over a one-year period (January 2023–December 2023). The study population comprised sports injury patients aged 16–40 years presenting with knee complaints during the study period. Patients with physician-confirmed prior ACL injury (surgical or non-surgical) were classified as cases, while those with other knee or sports injuries but no ACL involvement served as controls.

Inclusion criteria were: age between 16 and 40 years, history of regular sports participation (≥6 months), and ability to provide informed consent. Exclusion criteria included acute trauma within the past six weeks, major knee ligament or cartilage surgery within six months, neurological disorders, or conditions precluding anthropometric assessment.

Sample size was determined pragmatically, yielding 92 participants (18 with prior ACL injury and 74 without). Data collection procedures involved structured questionnaires for demographics, sport type, training exposure, and injury history. Anthropometric measures (height, weight, waist, hip) were obtained using standardized techniques. Body mass index (BMI) was calculated as kg/m². Body fat percentage was measured using a bioelectrical impedance analyzer (or Jackson-Pollock 3-site skinfolds where BIA was unavailable). Limb symmetry index (LSI) was derived from bilateral thigh circumference and, when available, segmental lean mass (LSI = 100 × weaker/stronger limb).

Among ACL-injured patients, functional outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee (IKDC) subjective form. Statistical analysis was performed using SPSS v26. Descriptive

statistics compared groups (t-test/χ^2). Logistic regression adjusted for age, sex, sport, and exposure hours evaluated associations. Model performance was assessed by area under the curve (AUC), calibration, and Brier score. Significance was set at $p<0.05$.

Results:

Patients with ACL injury (n=18) were slightly older (25.1 vs 23.7 years) and more often male (56% vs 38%) compared with controls. Competitive participation was notably higher in the ACL group (67% vs 43%), alongside greater weekly exposure (9.0 vs 7.4 hrs, p=0.04). Prior non-ACL knee injuries were more frequent (28% vs 18%), and median Beighton scores indicated greater joint laxity. Together, these patterns suggest increased training exposure and joint hypermobility may predispose to ACL injury.

Table 1. Participant characteristics by ACL status

Variable	No ACL (n=74)	Prior ACL (n=18)	Total (n=92)	p-value
Age (years), mean ± SD	23.7 ± 4.3	25.1 ± 4.5	24.0 ± 4.4	0.18
Sex: Male, n (%)	28 (37.8)	10 (55.6)	38 (41.3)	0.17
Sex: Female, n (%)	46 (62.2)	8 (44.4)	54 (58.7)	0.17
Level: Recreational, n (%)	42 (56.8)	6 (33.3)	48 (52.2)	0.08
Level: Competitive, n (%)	32 (43.2)	12 (66.7)	44 (47.8)	0.08
Exposure hrs/week, mean ± SD	7.4 ± 3.0	9.0 ± 3.3	7.7 ± 3.1	0.04
Previous non-ACL knee injury, n (%)	13 (17.6)	5 (27.8)	18 (19.6)	0.31
Beighton score, median [IQR]	2 [1–3]	3 [2–4]	2 [1–3]	0.09

ACL-injured patients showed elevated BMI (24.3 vs 23.2 kg/m²) and body fat % (21.9 vs 18.6), with waist-to-height ratio trending higher (0.48 vs 0.46). Segmental lean mass in the legs was reduced (16.0 vs 17.3 kg). Although BMI differences were modest, body composition measures aligned more strongly with injury, supporting the role of excess adiposity and reduced lean mass in ACL vulnerability.

Table 2. Anthropometry and body composition

Measure	No ACL (n=74)	Prior ACL (n=18)	Mean diff	p-value
BMI (kg/m²)	23.2 ± 2.8	24.3 ± 2.9	+1.1	0.11
Waist-to-height ratio	0.46 ± 0.05	0.48 ± 0.06	+0.02	0.07
Body fat %	18.6 ± 7.2	21.9 ± 7.5	+3.3	0.05
Segmental lean (legs, kg)	17.3 ± 3.2	16.0 ± 3.0	−1.3	0.12

Marked asymmetry was evident in the ACL group, with significantly lower LSI_thigh (92.4% vs 96.9%, $p<0.01$). These differences imply incomplete restoration of muscle balance after injury or chronic asymmetry preceding rupture.

Table 3. Limb symmetry and thigh measures

Measure	No ACL (n=74)	Prior ACL (n=18)	Mean diff	p-value
LSI_thigh (%)	96.9 ± 2.7	92.4 ± 5.1	−4.5	<0.01

Unadjusted models demonstrated that each SD rise in body fat % increased ACL odds by ~46% (OR 1.46, 95% CI 1.08–1.98), while each SD increase in waist-to-height ratio yielded a 40% higher risk. Conversely, improved thigh symmetry reduced odds by ~36%. BMI and Beighton scores trended in the expected direction but did not reach significance. These associations highlight modifiable body composition and asymmetry as key correlates.

Table 4. Univariable associations with prior ACL injury

Predictor (per 1 SD)	Crude OR	95% CI	p-value
BMI	1.29	0.92–1.82	0.13
Body fat %	1.46	1.08–1.98	0.01
Waist-to-height ratio	1.40	1.02–1.93	0.04
LSI_thigh (%)	0.64	0.45–0.90	0.01
Beighton score	1.18	0.95–1.47	0.12

After adjustment, body fat % remained significantly associated with ACL injury (aOR 1.42, 95% CI 1.06–2.02), as did lower thigh symmetry (aOR 0.69, 95% CI 0.50–0.95). BMI lost statistical significance (aOR 1.24, p=0.15). These findings suggest that detailed composition and symmetry measures, rather than crude BMI, provide stronger independent prediction of ACL risk.

Table 5. Multivariable logistic regression between two groups

Model / Predictor	Adjusted OR	95% CI	p-value
Model A (Body fat %)	1.42	1.06–2.02	0.03
Model B (LSI_thigh %)	0.69	0.50–0.95	0.02
Model C (BMI)	1.24	0.92–1.78	0.15

Among males, body fat % demonstrated stronger association with ACL injury (aOR 1.55, p=0.02) compared with females, with a significant interaction term (p=0.04). Symmetry effects were also accentuated (aOR 0.66, p=0.02). BMI again showed weaker and non-significant association.

Table 6. Subgroup analysis – Males

Predictor	Male aOR	95% CI	p-value	Interaction p
Body fat %	1.55	1.08–2.24	0.02	0.04
LSI_thigh (%)	0.66	0.47–0.93	0.02	0.09
BMI	1.28	0.90–1.86	0.16	0.26

Within ACL-injured athletes, higher body fat % predicted poorer KOOS-QoL (β=−4.5, p=0.01) and lower IKDC scores (β=−3.7, p=0.04). Better thigh symmetry predicted less pain (β=+3.8, p=0.01). Explained variance was modest (R^2=0.15–0.22), yet clinically relevant. These findings imply that persistent body composition and symmetry deficits are linked with suboptimal recovery.

Table 7. Prior ACL only: Knee function outcomes

Outcome	Predictor	β (per 1 SD)	95% CI	p-value	R^2
KOOS QoL	Body fat %	−4.5	−7.9 to−1.1	0.01	0.19
KOOS Pain	LSI_thigh %	+3.8	+1.0 to+6.6	0.01	0.22
IKDC	Body fat %	−3.7	−7.1 to−0.3	0.04	0.15

Sensitivity checks confirmed robustness: obesity was linked with nearly doubled odds of ACL injury (OR 1.90, p=0.05), and body fat % remained predictive when restricted to non-contact injuries (aOR 1.45) and after excluding recent cases (aOR 1.37). Substituting skinfold %fat reproduced similar effects.

Table 8. Sensitivity analyses

Scenario	Effect estimate	95% CI	p-value
BMI Obesity vs Normal	OR 1.90	1.01–3.58	0.05
Non-contact ACL only	aOR (bf% per SD) 1.45	1.04–2.01	0.03
Exclude injuries <12 mo	aOR (bf% per SD) 1.37	1.02–1.86	0.04
Replace with skinfold %fat	aOR (per SD) 1.34	1.01–1.78	0.04

Discussion

This cross-sectional study showed that higher body fat percentage and reduced limb symmetry were significantly associated with ACL injury among sports injury patients. The demographic profile revealed that injured patients were slightly older (mean 25.1 vs 23.7 years), with a higher proportion of males (55.6% vs 37.8%) and greater exposure hours (9.0 vs 7.4 h/week). Although our sample was modest, these differences were inconsistent with epidemiological reports where female athletes demonstrate up to a fourfold higher risk of ACL rupture compared with males [8,9]. Competitive participation was also more common in the injured group (67% vs 43%), supporting prior evidence that higher training intensity and match exposure elevate ACL injury likelihood [10].

Body composition emerged as a stronger correlate of ACL injury than BMI. Our findings align with Buck et al., who reported that fat percentage, not BMI, predicted poorer clinical outcomes after reconstruction [8]. Triplett et al. similarly found women with prior ACL injury had higher adiposity and lower cardiorespiratory fitness [17]. In our sample, each SD increase in body fat % increased the odds of ACL injury by 42%, while BMI showed no significant effect. Obesity has also been linked to longer hospital stays and worse recovery trajectories after ACL surgery [14,15], suggesting that body fat influences both risk and prognosis. Reduced limb symmetry was another independent correlate, with injured patients demonstrating ~4–5% lower LSI. This agrees with Simonsson et al., who cautioned against over-reliance on LSI due to potential overestimation of function [9], and Wellsandt et al., who showed that symmetry indices may mask bilateral weakness [10]. Importantly, longitudinal studies demonstrate that asymmetry predicts persistent symptoms years after injury [12].

Our study is limited by its cross-sectional design, modest sample (n=92), and hospital-based recruitment, which may reduce generalizability. However, sensitivity analyses confirmed robustness, and findings mirror those from larger prospective cohorts [11,13,16,18,19]. Advanced approaches, such as EMG-based asymmetry detection [20] and biomechanical modeling [21,22], may further clarify mechanisms.

In summary, sports injury patients with ACL involvement exhibited greater adiposity, reduced muscle symmetry, and higher competitive exposure. Integrating body composition and symmetry measures into orthopedic screening could enhance early identification of at-risk patients and improve rehabilitation outcomes.

Conclusion

Sports injury patients with ACL injury had higher body fat, reduced limb symmetry, and greater weekly exposure than controls. Body composition and symmetry were stronger predictors than BMI and were linked with poorer knee function. Incorporating these measures into orthopedic screening and rehabilitation may improve risk identification and patient outcomes.

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